International Journal of Computers, Communications & Control
Vol. I (2006), No. 2, pp. 33-40

The Challenge of Designing Nervous and Endocrine Systems in Robots

Felisa M. Córdova, Lucio R. Cañete

Abstract: We discuss in conceptual terms the feasibility of designing a Nervous System and an Endocrine System in a robot and to reflect upon the bionic issues associated with such highly complex automatons. The emulation of biological phenomenon in artificial systems, both nervous and endocrine imitation in a mechatronic automaton is an attractive proposition as a mechanism of organic integration. The ability of living organisms to maintain their internal organization in spite of external changes, encourages attempts to imitate such achievements in devices. The complexity of the network sensors-integrators-effectors and the proportion of internal fluids must be increased when seeking the homeostasis of the robot from mechatronic design to bionic design.
Keywords: bionics, integration, robots.

1 Introduction

Biology has developed in a very accelerated way over the last three decades with the 21st Century, widely predicted to be the "Biology Age" (Ovchinnikov, 1987). In this context, a certain interest in emulating biological characteristics in appliances can be seen, for the purpose of recreating the successful behavior of living organisms in artificial systems.

Sensors such as hair and skin, effectors such as feet and fins and integrators such as artificial brains are some examples of bionic projects (Cañete, 2002). However, in order to come close to achieving the behavior exhibited by animals as inspiratory beings, then by necessity (Ofek, 2001), it must be recognized the pertinence of Nervous System and Endocrine System.

Of course, when the Nervous System and the Endocrine System work in unison in animals, they could generate synergic effects in the behavior of these alive beings. The use and integration of both systems in a human being can be seen for example when a person is attacked by a swarm of wasps. The electromagnetic receptors (the eyes), acoustics (the hearing) and those related to pain (the skin) receive information which is interpreted as threatening, so the association neurons and effectors not only order the locomotors effectors (the leg's skeletal muscles) to take flight but also order the glands to release adrenaline and other hormones that designate resources to the task of escaping.

No doubt, animal characteristics like these are interesting to emulate in automatons (Cañete and Córdova, 2003). So, the objects of this work are to conceptually design a Nervous System and Endocrine System in robots as a biological emulation, and to reflect upon the bionic design of those systems.

2 Why a nervous system and a endocrine system?

On examining any animal, one observes that the digestive, circulatory, respiratory and excretory systems have specific structures and functions, but none of them can carry out their functions independently of the others; rather they work together in harmony to meet the metabolic needs of the body. Any living being, not only an animal, is an organized entity that behaves as a unit and this unity is the result of the participation of a larger coordinated and integrated system. As an automaton, a robot must also possess such a system, and select animal inhalation as a perfect example of how it must fit together with its environments.

Vertebrates and other multicellular beings whose structures are the result of the evolution (Paccault, 1991), the source of the emulation, posses two coordination systems of varying form and complexity that are closely related: Nervous and Endocrine. Both serve to make the body a unique active entity, individually regulating the functions of it parts and enabling it to adjust to changes.

In biology texts, robots designers are accustomed to seeing both systems compared with each other with the emphasis on the considerable difference that exist between them: in the Nervous System the message is an electrochemical disturbance (a nerve impulse) that travels through a nerve fiber, whereas in the Endocrine System the message is a chemical substance (a hormone) that travels in fluid, like blood.

If a robot had a sort of these system, it behavior in aggressive environments would be better. So, as it shown in Figure 1, the immediate task is to emulate the Nervous System and the Endocrine System from natural stage to artificial stage (animal to robot).

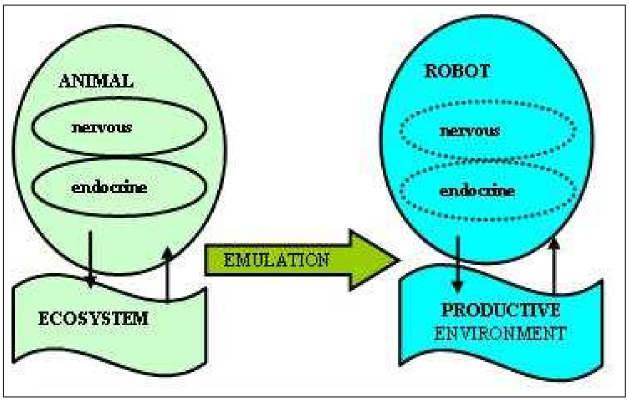

Figure 1: From a scene of origin towards another one of destiny. Considering the contribution of the Nervous System and Endocrine System to the successful performance of the animal facing its ecosystem, such systems conceptually may be copied in a robot to face its productive environment

3 The nervous system

3.1 The necessity of sensors

It is possible to face the design of basic a Nervous System that allows to make the sensomotor coordination to guide a Load-Haul-Dump (LHD) vehicle inside a street within a tunnel in an underground mine (Córdova, 1996). The vehicle loads mineral from a pit and it dump it in a ore-pass. Then, a set of sensors could be in charge to acquire the relevant data from the tunnel. Among them, is possible to use some of the following ones:

- Distance sensors, that can be an adjustment of ultrasonic sensors, or infrared sensors.
- Laser sensors to measure depth.
- Tact and of proximity sensors.
- Vision sensors, that uses TV cameras and processors of stereoscopic images, that can detect a painted line in the ceiling of the gallery or the profile of the tunnel.
- Angle sensors.
- Torque and acceleration sensors.
- Sensors of virtual surroundings, that can detect them holes of ditches and resentments.

- Sensors of the operational conditions of the vehicle, among them sensorial of humidity, temperature, pressure.
- Sensors of environmental conditions of the tunnel, such as fire detectors.
- Tags, that allows to detect figures of bar codes and it the location of the vehicle inside the gallery.

3.2 A sensomotor coordination design

In this particular design, an array of six located ultrasonic sensors in the flanks of the vehicle is used. The navigation criteria is of homeostatic type, that means that the vehicle maintains a equidistant distance to the walls of the tunnel. In this design, a neuronal network of sensomotor coordination can be used that coordinates the sensors and the actuators. The strategy of sensomotor coordination makes use of a propioceptive network presented in Figure 2.

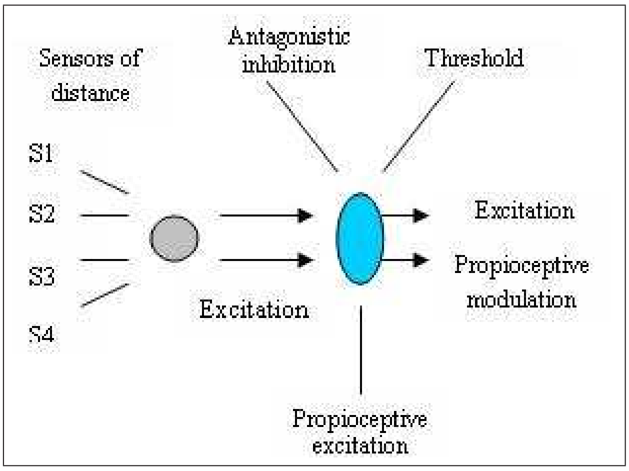

Figure 2: Propioceptive network

In the reflective network of senso-motor coordination of Figure 3, from the general and previous design of a fuzzy neuron, defined the characteristic of design for each neuron in individual, obtaining itself eight types of neurons. In the case of the sensorial neuron a not-linear excitation (sigmoidal) and with different weight for each sensor from the respective sub-network is required (the Agonist-Antagonist sub-networks are symmetrical in their construction).

Modulating Neuron **m** dynamically varies the characteristic of the Excitatory Neuron **e1** and the Threshold Neuron. This activity of modulation is function of the speed of the vehicle and the ratio of turn **Rg**. The rest of the neurons has excitatory and/or inhibitory activities according to its connectivity in the network.

The rank of activity of all the neurons varies between 0 and 1, minimum activity and maximun activity for all the variables of the neurons. The signals of activity are Excitation, Inhibition, Modulation and a Threshold of adjustment for each neuron.

- Excitatory Neuron e1: this neuron receives the activity of the distance sensors whose weight decreases and this is modulated as well by the activity of the Modulating Neuron depending on inverse on the turning ratio and the speed of vehicle v at low speeds and v2 at high speeds (over v2 march).
- Excitatory Neuron e2: this neuron actives the turn actuator, receiving a modulated activity of the previous activity of its sensors, inhibitions of the antagonistic network that are against to him and of its own actuator that restrains it and stabilizes as the networks arrive at an activity balance.

- Inhibitory Neuron i1: this neuron allows the incorporation of the activity from one sub-network to the other, and its action is strong in high ranks of internal activity to allow to a fast compensation forehead to strong stimulus of the network that originates it when the networks are very far from the balance.

- Inhibitory Neuron i2: this neuron restrains the activity of the turn actuator when it is in conditions near the balance, or allows a fast turn (depending on the Threshold Neuron) when a strong sensorial activity of distance exists and the vehicle goes fast.

- Modulating Neuron m: this neuron modulates the activity of sensors of distance in agreement with the speed and the turning ratio of the vehicle, in addition stimulates to the neuron threshold when its own activity is high along with the activity of the distance sensors.

- Threshold Neuron: When this neuron is stimulated by the Modulating Neuron, it inhibits to inhibitor of the actuator to correct in fast form the direction of the vehicle. This is required in the case that the vehicle has a small turning radius or when the speed is high.

- Sensor Neuron: The activity received by each sensor of the sub-network is heavy in decreasing form while more moved away it is of the advance direction, in addition the sensation one to the activity is not-linear for each sensor.

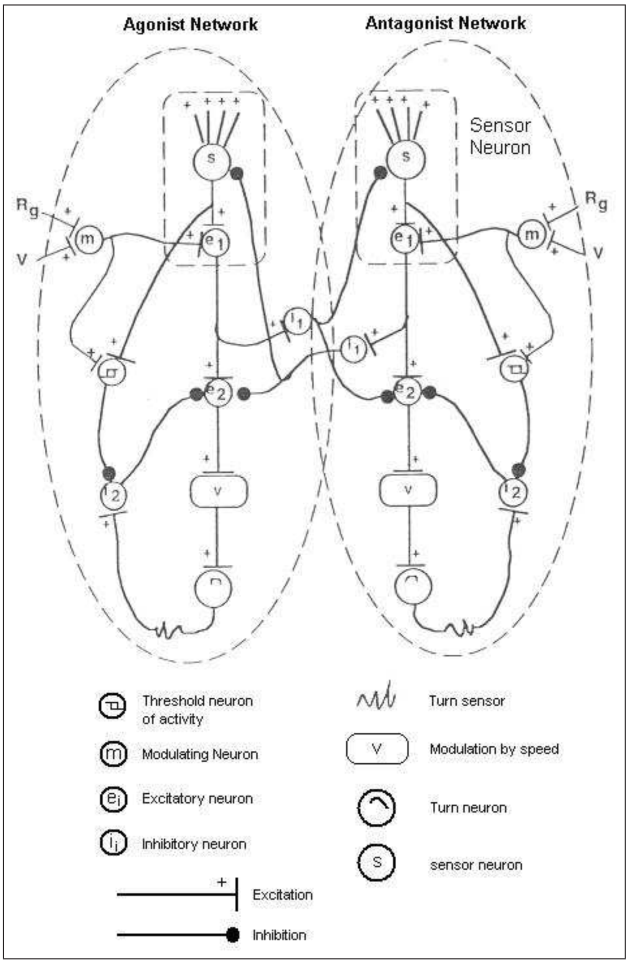

Figure 3: Sensomotor network

Structurally speaking, nerves can be emulated and in fact they have been, by way of electrical conductors specifically in mechatronic automaton like LHD.

4 The endocrine system

4.1 The necessity of an internal fluid

In the case of blood, it has not been emulated in robots and the absence of internal fluid in an automaton was one of the reasons why work was halted on the emulation of other animal features dependent on internal chemical transportation.

Of course, the existence of fluids in the body of the robot would not only facilitate the emulation of the Endocrine Systems' own hormones but also the emulation of antibodies for immunity, of bradicins (when animal tissue is broken, enzymes are released that convert certain plasmatic proteins into a substance called bradicin), for nociception (perception of damage) and of solvents for quimosensitivity (to stimulate the sense of taste, the chemical substances must be dissolved).

Furthermore, a fluid not only facilitates the movement of intra-corporal messengers but could also act as a lubricant, combustible and a thermo-regulator.

A classic mechatronic robot contains in percentage terms of volume approximately one sixth part of fluids which are principally lubricants, and substances for hydraulic devices and combustion. An arthropod on the other hand, contains at least three quarter parts of fluid (Cañete and Córdova, 2003).

Therefore, the first challenge in this respect consists of the proportion of internal fluids in the robot. Such an increase would lead to an increase in homeostasis which would bring with it an increase in the design complexity as shown in Figure 4.

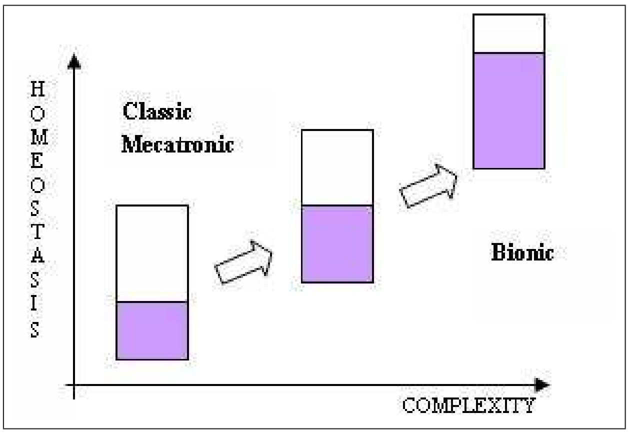

Figure 4: Complexity versus homeostasis. An increase in complexity for Endocrine System, comes with increasing the proportion of internal fluids when seeking the homeostasis of the robot from mechatronic design to bionic design

4.2 A simple design

When a robot works in changing environments, some parts of the surroundings without its control would become dangerous. In such situations, the robot will have to react in urgent form to fit its internal structures and to assure its viability. One of such urgencies can be the repair or reinforcing a part of the body that is being exposed to an external requesting. In order to face such situation it is possible to be resorted to a endocrine emulation as it is explained next and presented in Figure 5.

The internal part of the sensible zone of the body exposed to harmful emboss and ruptures are designed rough and it is covered with little smooth laminas.

The last ones are conductive elements with bad plastic behavior; of such form get fractures and can release them when happens a damage of the outside.

The internal part in addition is bathed by a fluid and slightly energized with electrical current.

An internal sensor to the circuit of the fluid exists somewhere in addition that is able to capture fragments of little laminas conductors by magnetic action. Whenever it captures some piece of laminas, releases a plastic and rough substance in form of grume (small semisolid mass) and it orders to a pump to increase the speed of the fluid circulation. The rough grumes slide by the smooth surface and they are crowded in the rough surface that is being dangerous. Finally the grumes reinforce the exposed zone.

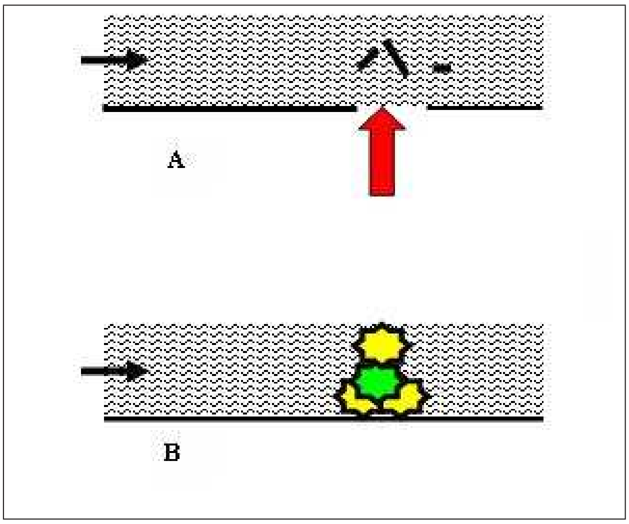

Figure 5: Cross section of the bodywork with phenomenon of endocrine emulation.
A: An external agent breaks or damages the interior where a fluid circulates, conductive fragments are freed in the open leaving one rough surface. The fragments when traveling by the fluid are captured by a magnetic receiver that releases rough grumes.
B: The rough grumes travel by the current and they lodge in the naked zone, cushioning the external action. The effect on the speed flow caused by the grumes is insignificant due to the extension planar of the conduit and to the precise location of the grumes.

Why not to design a hard bodywork and thus to avoid a complex Endocrine System? For the same reason for which the nature through million years of evolution has not done it (David and Samadi, 2000). Comparatively (Massé and Thibault, 2000), to maintain a hard bodywork is more expensive than to maintain a light bodywork with repair capacity.

5 Organic integration in the robot

Once the Endocrine and Nervous Systems have been conceived, both systems may be connected to each other and at the same time joined to the functions which they control. It is then that an organization is configured, which for the purpose of the robot being proposed in the current research, would have a internal communication structure as shown in Figure 6.

In animal kingdom, the levels are recursive and thus subordinates: that is to say the Supreme Level contains and governs the Homeostasis Level (Nervous and Endocrine) which in turn does the same with the Sensomotor Level.

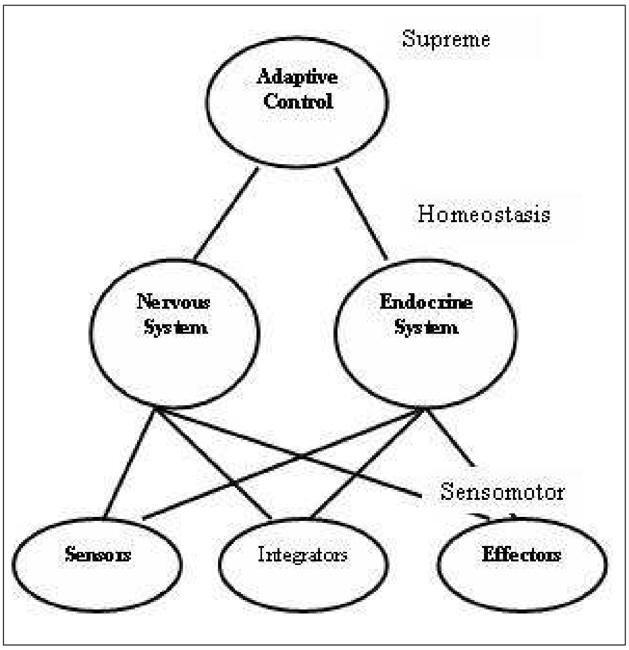

Figure 6: Three levels in organic integration of bionic robot. The nervous and endocrine reaction corresponds at a Homeostatic Level. Such reactions are subordinated to Supreme Level, but they govern at Sensomotor Level.

Adaptive Control, as the name implies, is the higher level of coordination and functional integration in a robot. Its structure can be a managed by a system that knows the mission the robot and links both information of the inner state of the automata and his surroundings. A proposed future challenge in the present work, is the conceptual design of this Adaptive Control.

6 Conclusions

Although the robot has neither nerves nor blood where it may send messages in charge of functionally integrating and coordinating all its parts, they can be emulated.

There is evidence that the emulation with certain restrictions of both Nervous and Endocrine System is feasible. However such an emulation would require the convergence of two sciences: Biology and Robotics.

The convergence of Biology with its different branches (Ecology, Genetics, Evolution among others) and Robotics is no accidental; rather it constitutes an essential issue in as far as abstract terms are concerned, that is: there is little to distinguish automatons and living beings. In reality both beings show behavior that is autopoietic (self produced), telenomic (self initiating) y homeostatic (self regulating with feedback function). Put more precisely: many of the features of a living being are desirable in an automaton.

Aspiring to have such features comes from the observations that man has carried out in the biological world of he himself is a part. The ability of living organisms to maintain their internal organization in spite of external changes, encourages attempts to imitate such achievements in devices, whose internal compositions are quite modest when compared with those of plants and animals.

This motivation, which has further increased on the verification of real successes achieved by man more than three decades ago (in sonar, prosthesis and artificial neuronal networks among others) provides a particular incentive to continue with the current research.

References

[1] Cañete, L., *Ecología cognitiva en robots terrenos para el desierto de Atacama*, Tesis Doctoral, Facultad de Ingeniería de la Universidad de Santiago de Chile, 2002.

[2] Córdova, F., *Guiado autónomo de equipos cargadores frontales LHD en una mina subterránea*, Informe Proyecto FONDEF. CONICYT. Chile, 1996.

[3] Cañete, L. and Córdova, F., Ecología cognitiva en robots terrenos, *Proceedings of the First IEEE Latin American Conference on Robotics and Automation LCRA*, Santiago de Chile, 2003.

[4] Cañete, L. and Córdova, F., A robot with immunity and perception of damage, *Proceedings of the First IEEE Latin American Conference on Robotics and Automation LCRA*, Santiago de Chile, 2003.

[5] David, P. and Samadi, S., *La théorie de l'évolution*, Paris: Champus Université Flammarion, 2000.

[6] Glávic, N. and Ferrada, C., *Biología. Tercer año de Educación Media*, Santiago: Ministerio de Educación, 1985.

[7] Ofek, H., *Second Nature: economics origins of human evolution*, Cambridge: University Press, 2001.

[8] Ovchinnikov, Y., *Basic Tendencies in Physico-Chemical Biology*, Moscow: MIR Publisher, 1987.

[9] Massé, G., and Thibault, F., *Intelligence économique*, Bruxelles: De Boeck Université, 2001.

[10] Paccault, I. (1991). La terre et la vie. Paris: Larousse.

Felisa M. Córdova, Lucio R. Cañete
Universidad de Santiago de Chile
Departamento de Ingeniería Industrial
Laboratorio de Concepción e Innovación de Productos, LACIP
Santiago de Chile
E-mail: fcordova@usach.cl